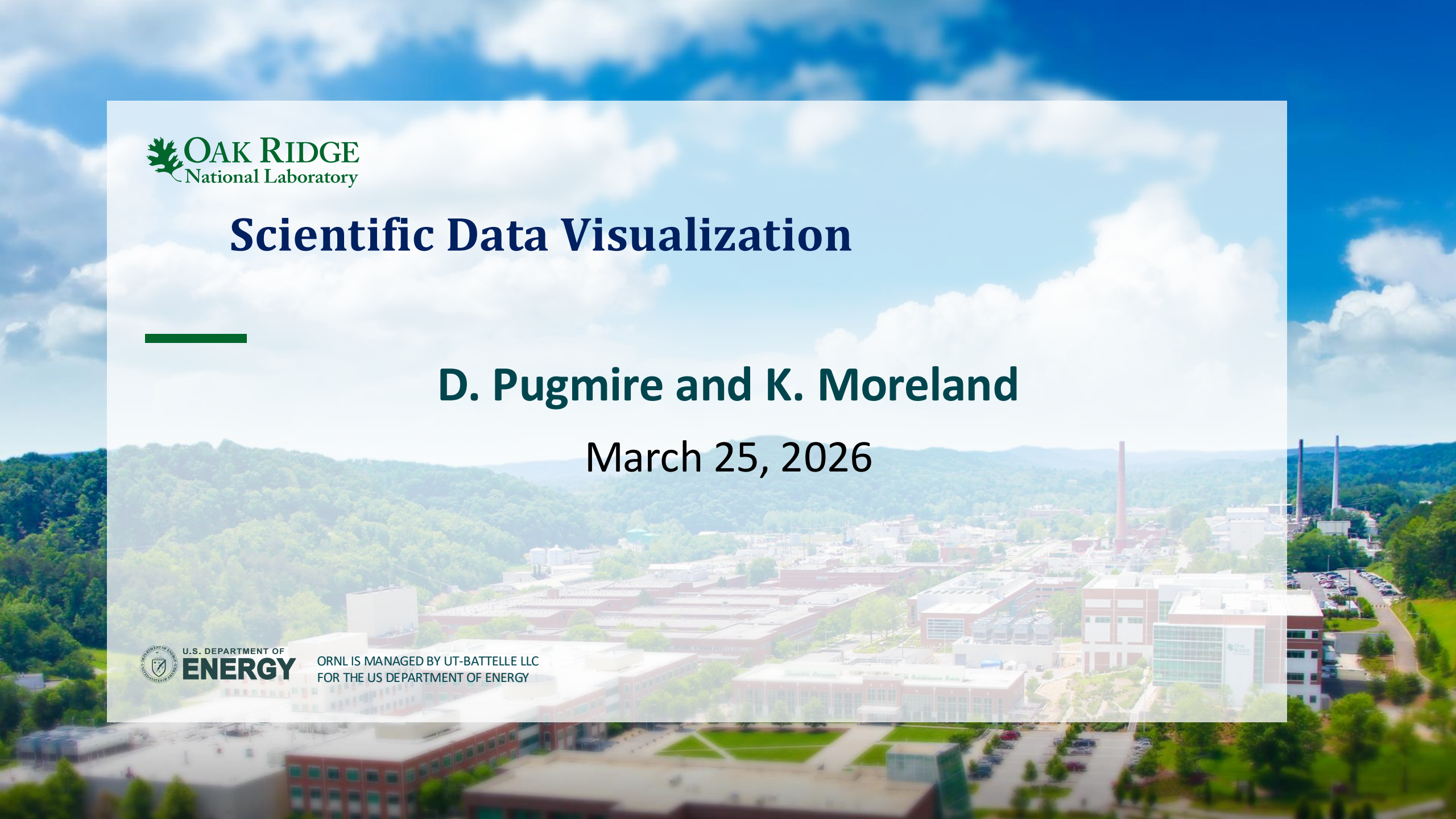


OAK RIDGE National Laboratory

Scientific Data Visualization

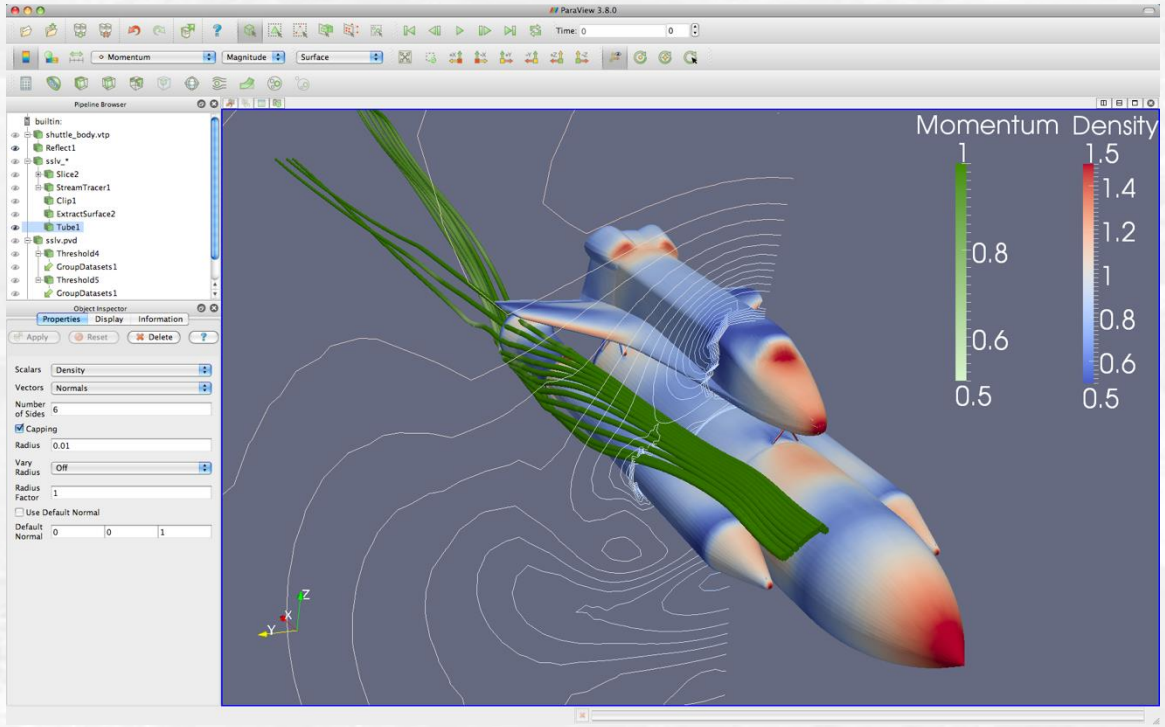
D. Pugmire and K. Moreland

March 25, 2026

Introduction

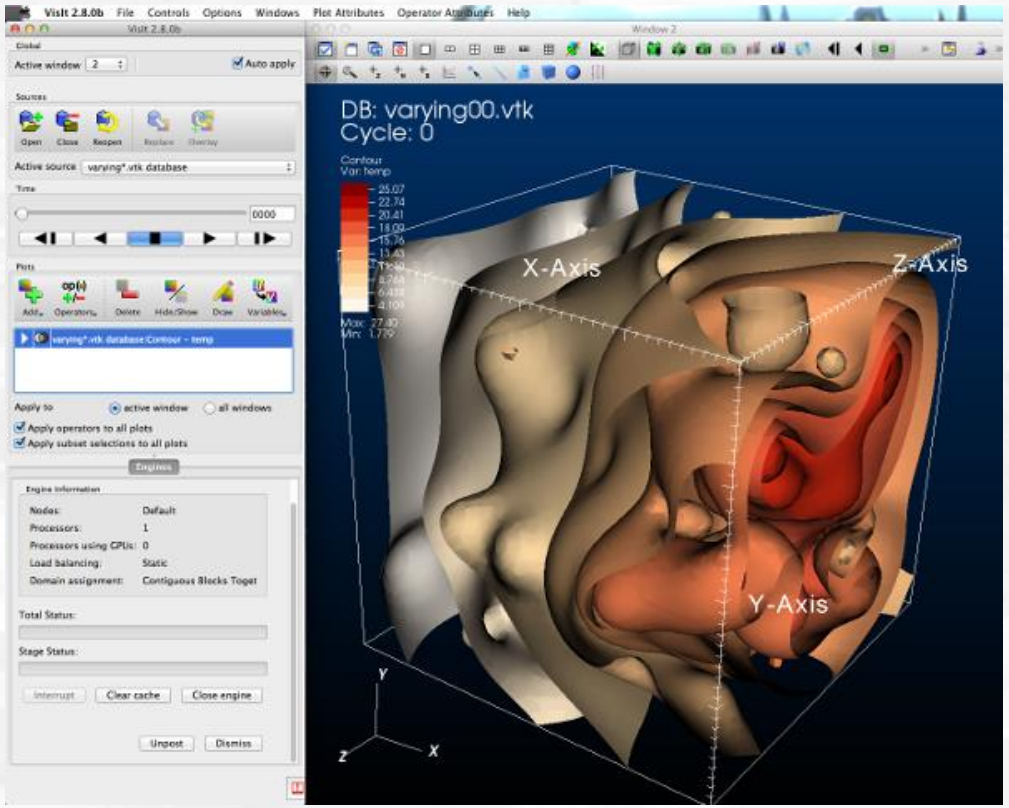
- Dave Pugmire
  - 17 years at ORNL, 5 years at Los Alamos working with very large data
  - Developer: VisIt, Viskores
- Ken Moreland
  - 5 years at ORNL, 20 years at Sandia supporting scientific visualization of very large data
  - Developer: ParaView, VTK, Viskores

Large-Scale Scientific Visualization Tools



ParaView

https://paraview.org

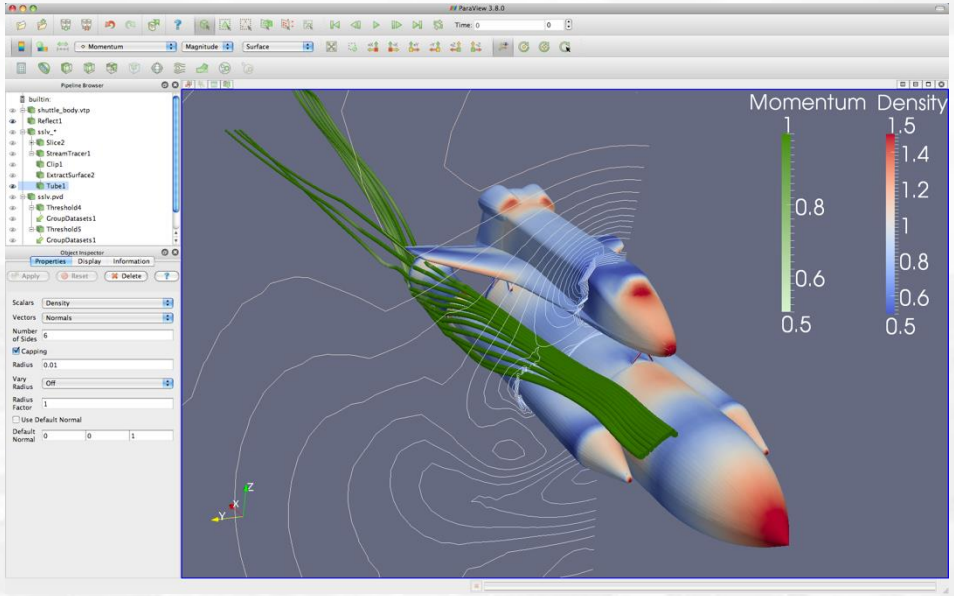


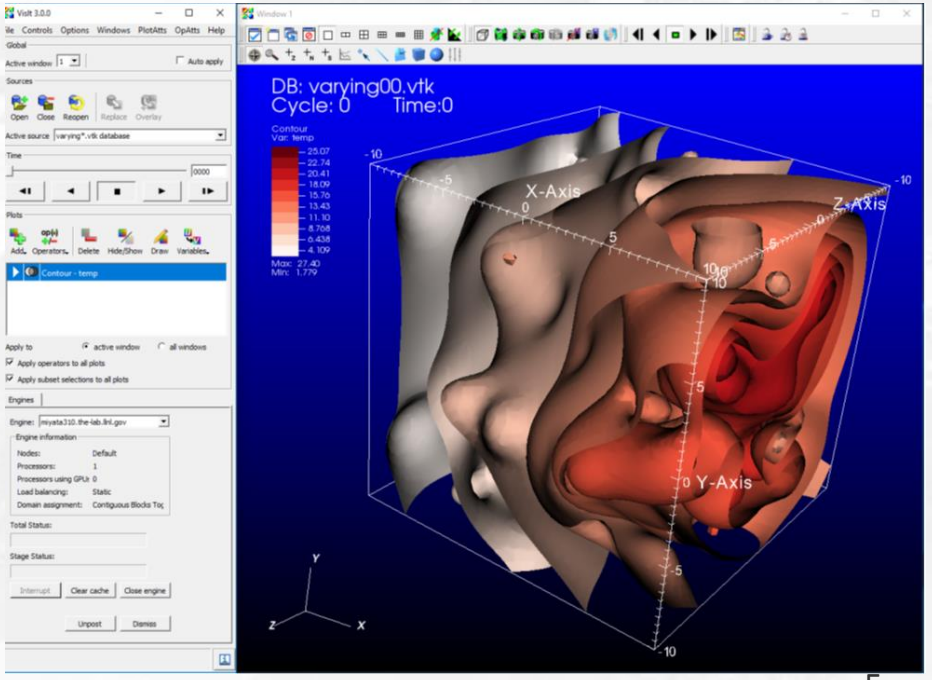
VisIt

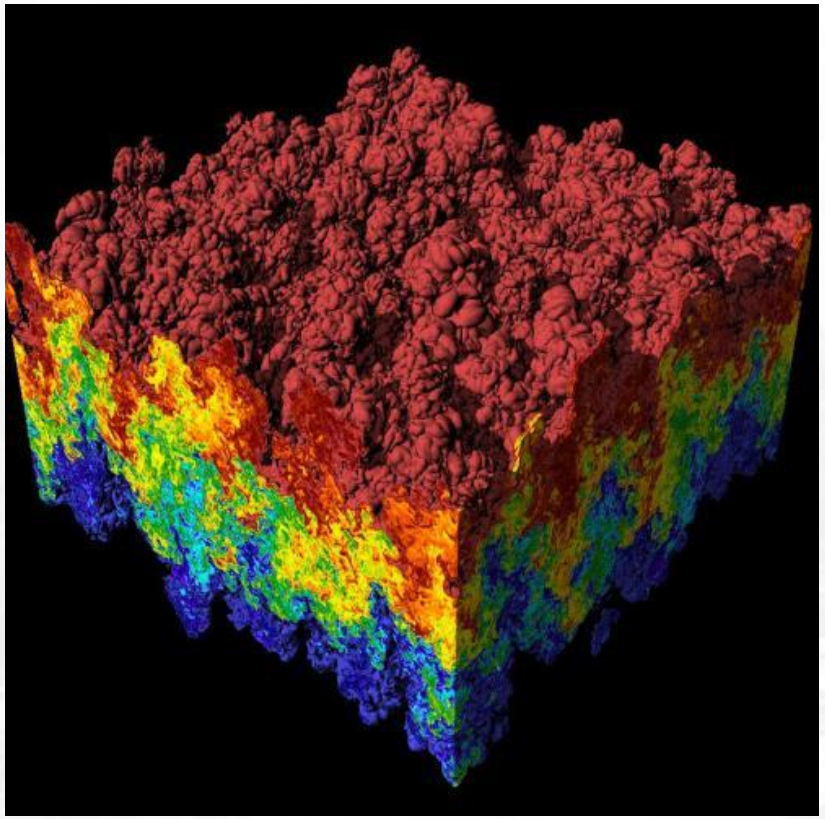
https://visit.llnl.gov/

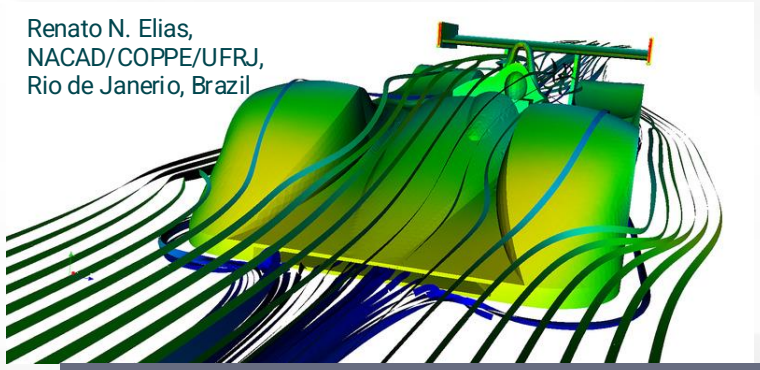
Visualization Tools Available at OLCF

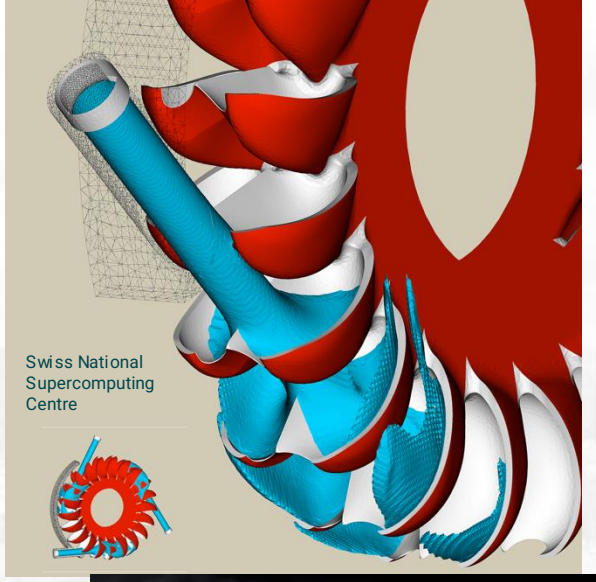
- ParaView, Visit
  - Fully featured production analysis and visualization
  - Support for 100s of file formats
  - Rich set of 1D, 2D, 3D visualization techniques
  - Python scripting
- Documentation
  - VisIt: ReadTheDocs
  - Paraview: Help → ParaView Guide
- Tutorials
  - VisIt tutorials:
  - Paraview tutorials: Help → ParaView Self-directed Tutorial
  - Lots of content on YouTube

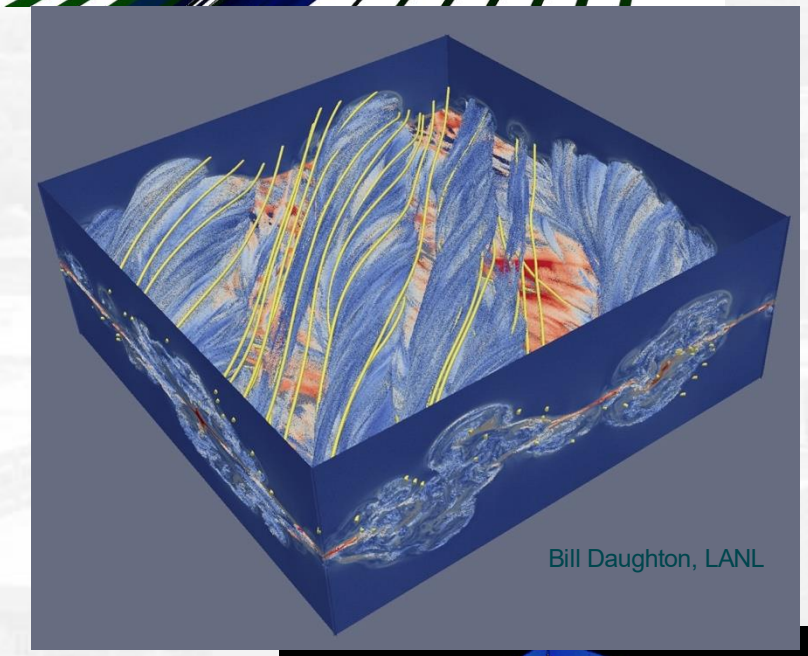


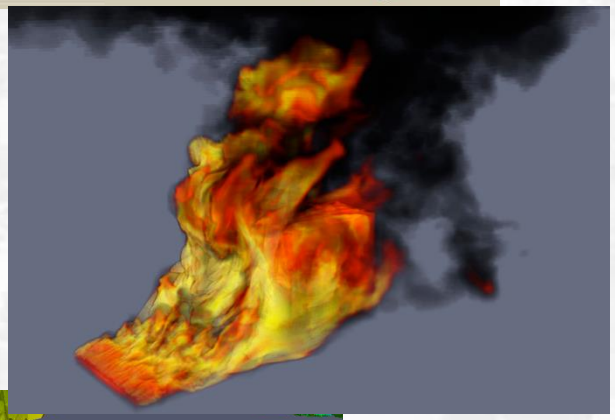


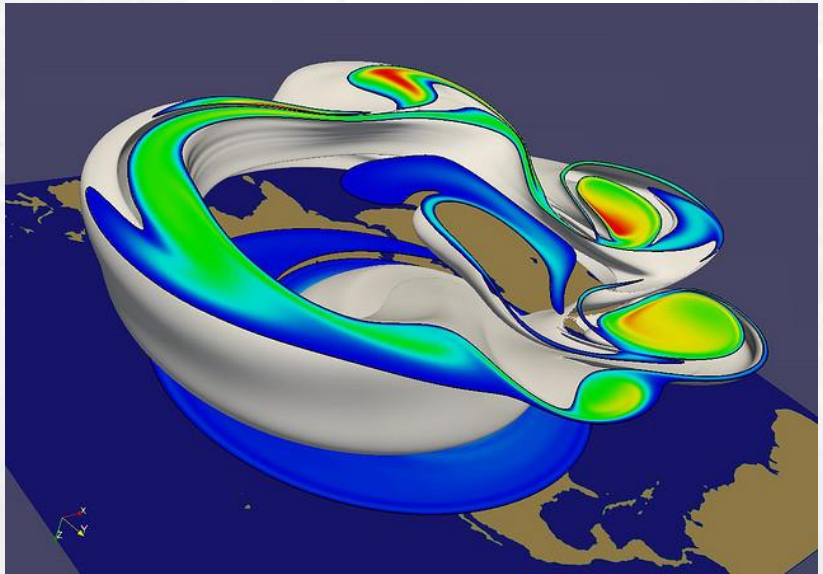


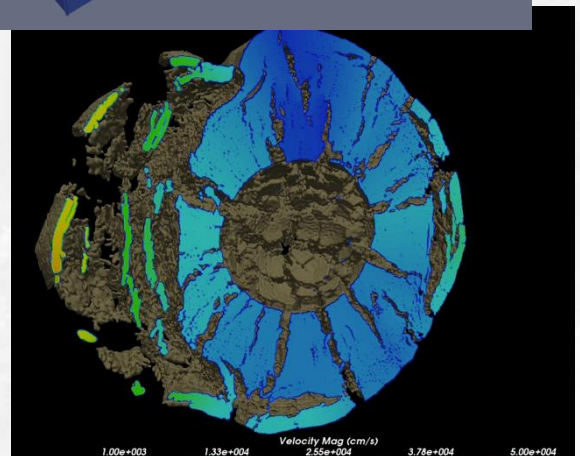

Renato N. Elias,
NACAD/COPPE/UFRJ,
Rio de Janerio, Brazil

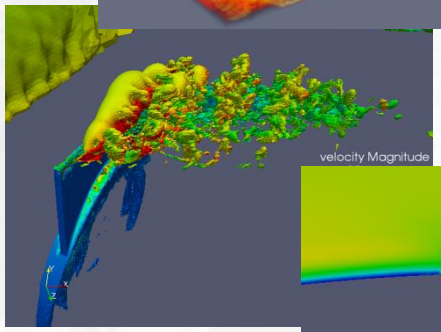

Swiss National
Supercomputing
Centre

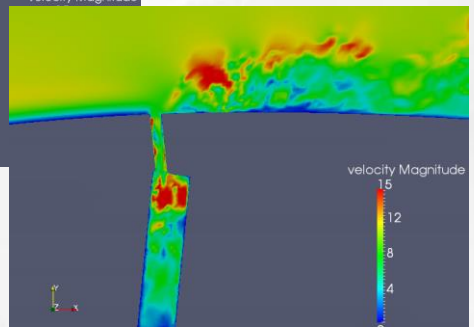

Bill Daughton, LANL



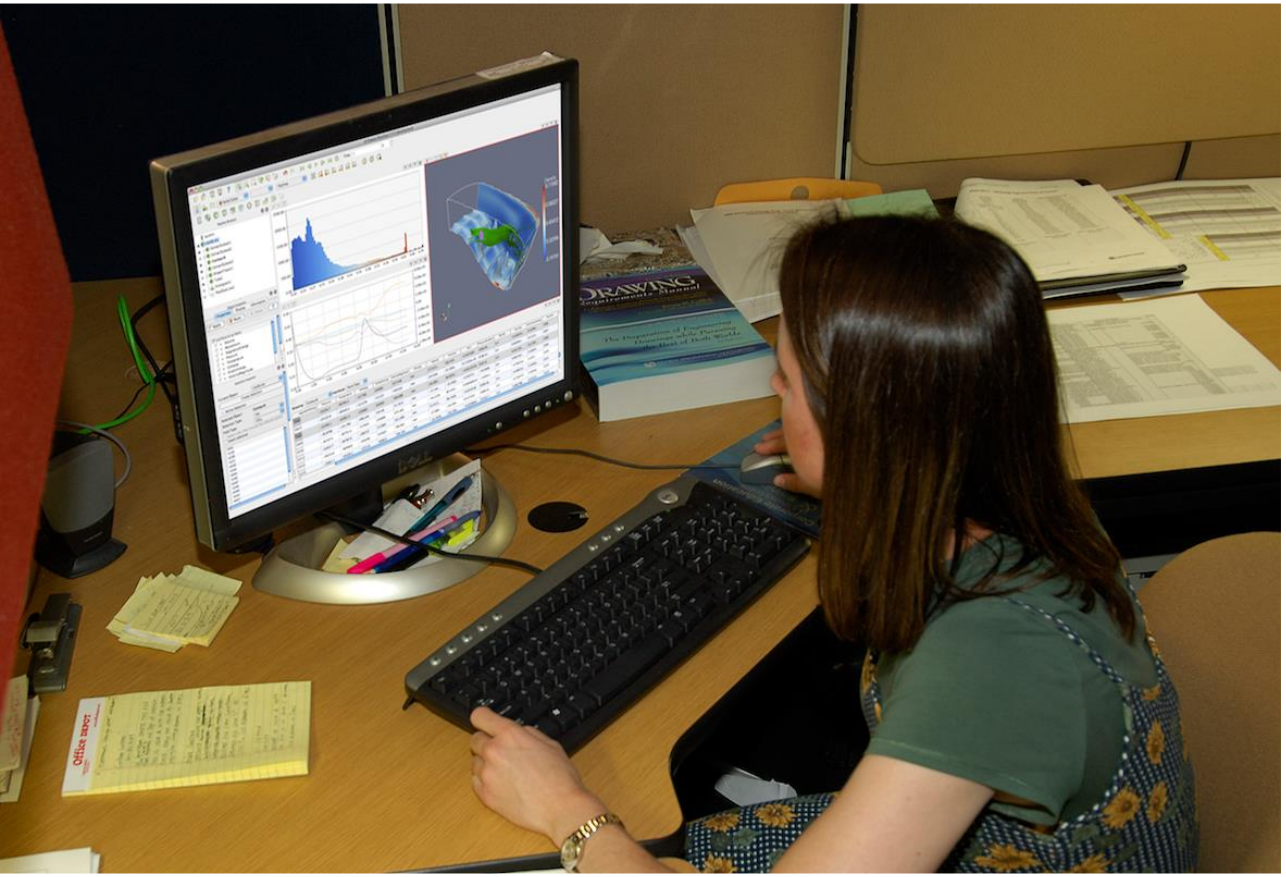



Velocity Mag (cm/s)
1.00e+003
1.33e+004
2.55e+004
3.78e+004
5.00e+004


velocity Magnitude

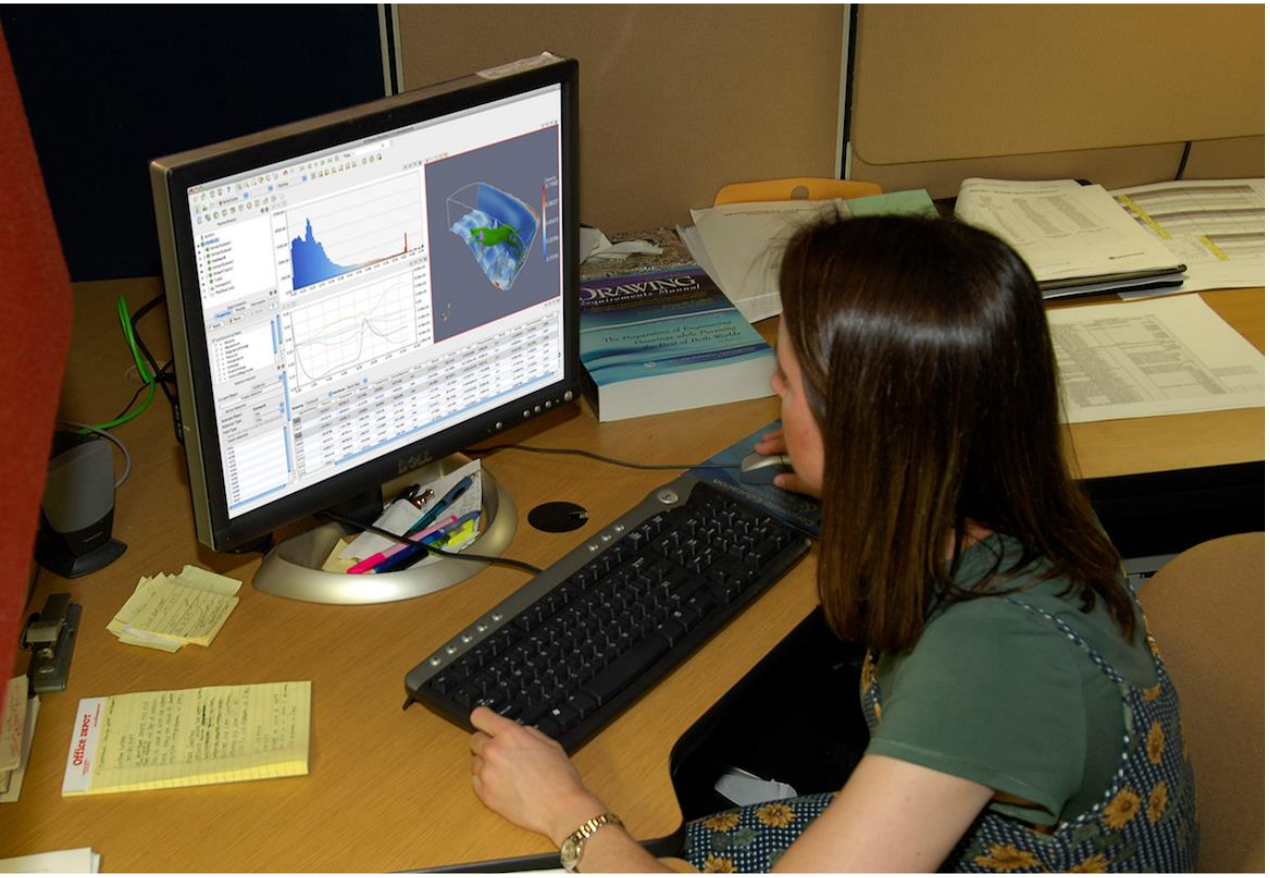

velocity Magnitude
15
12
8
4

The ParaView/VisIt HPC User Experience

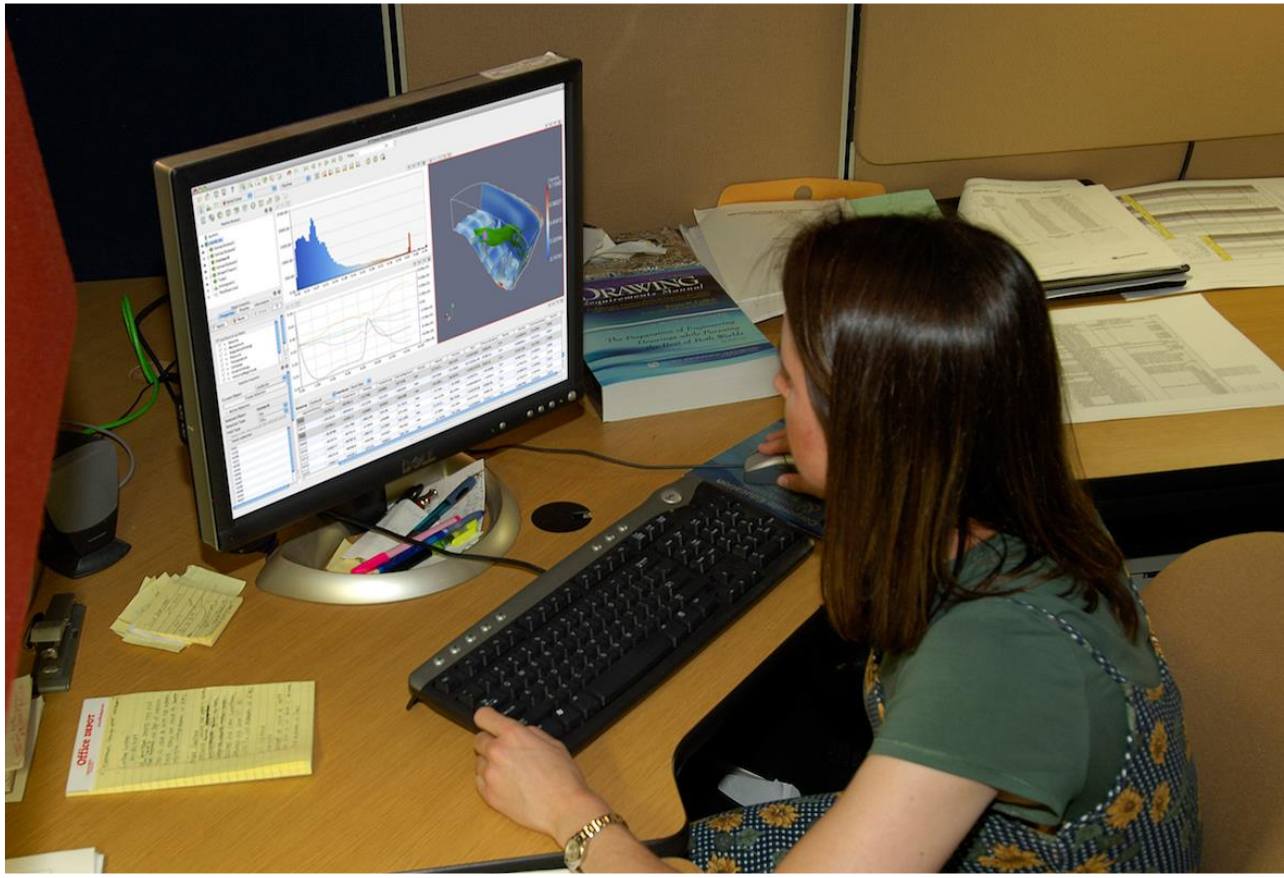


Using ParaView or VisIt on a small dataset run locally on your desktop or laptop.

The ParaView/VisIt HPC User Experience

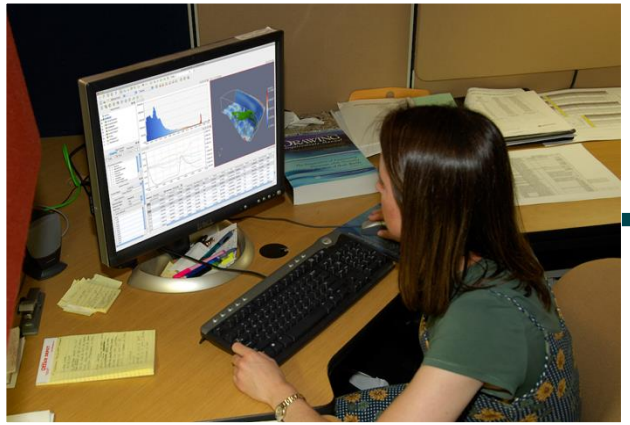


Using ParaView or VisIt on a small dataset run locally on your desktop or laptop.

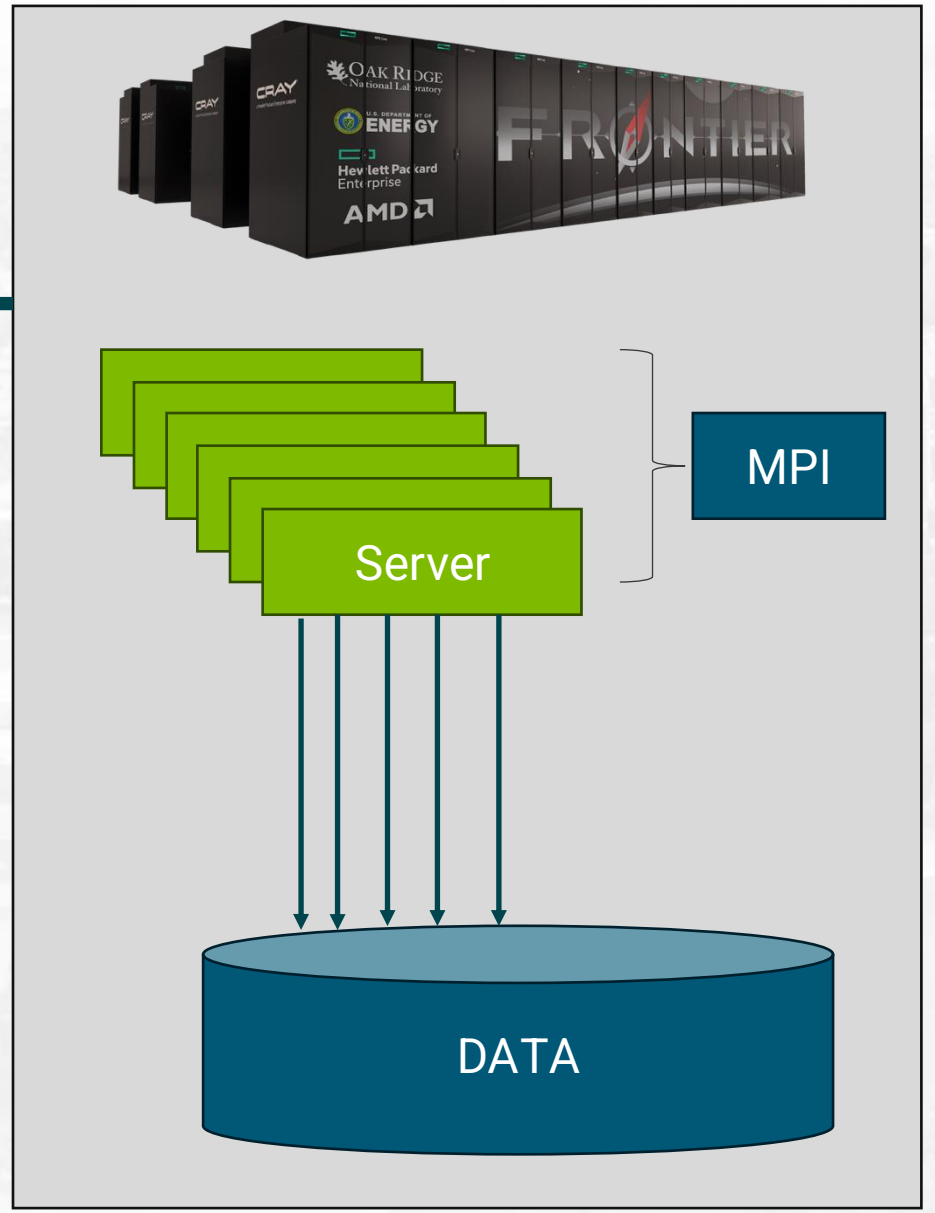


Using ParaView or VisIt on a large dataset of billions of cells run on thousands of cores at OLCF (Andes or Frontier)

Client-Server Architecture Makes Large Data Computation on OLCF Accessible

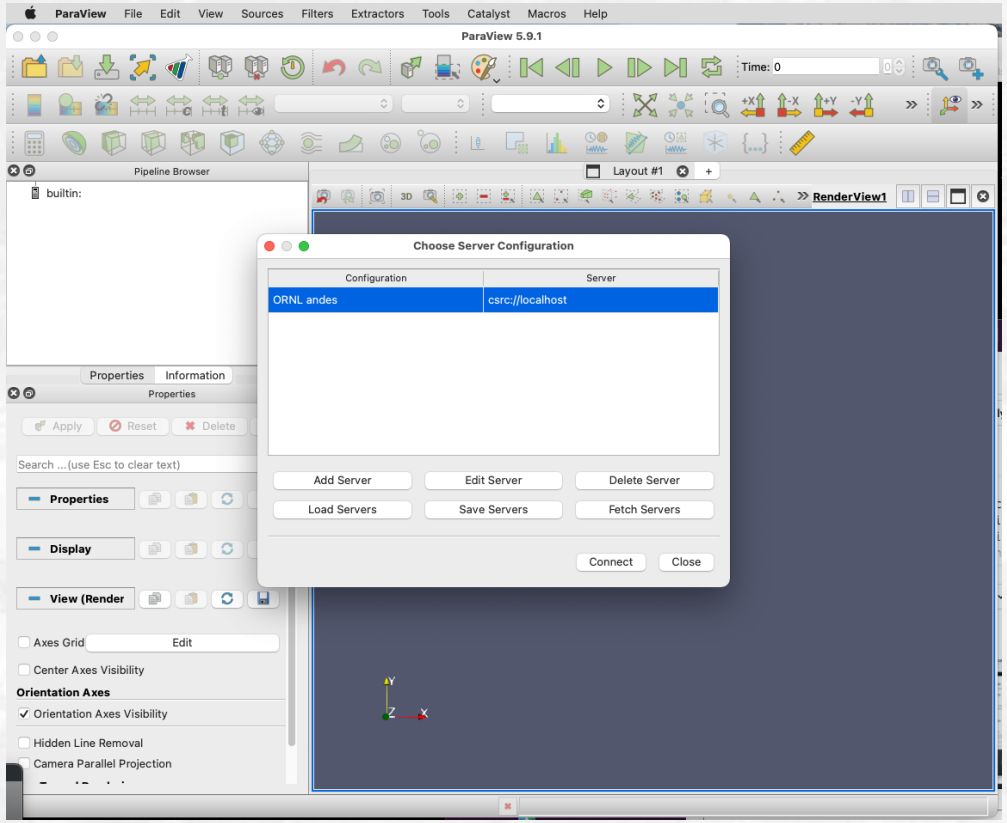


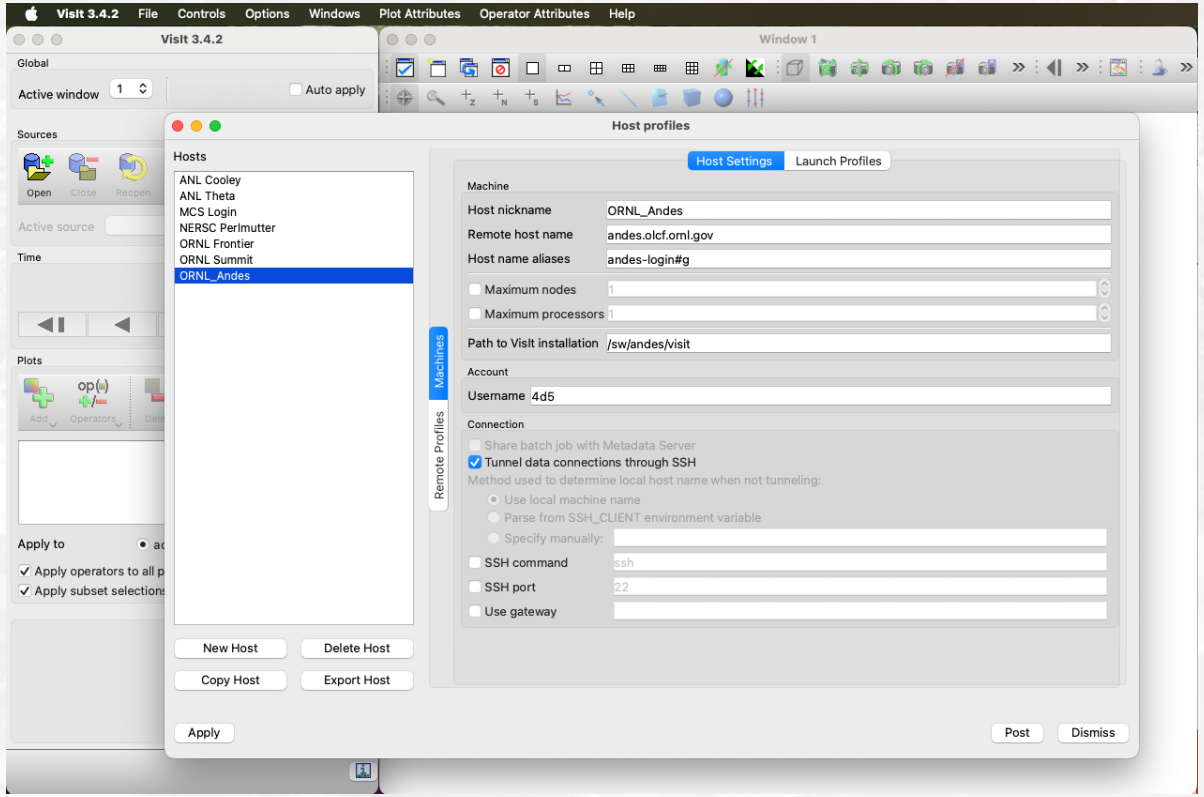
LAN/WAN



Running on OLCF

- See OLCF Users Guide → Software → Visualization Tools
- https://docs.olcf.ornl.gov/software/viz_tools/





Visualization Examples

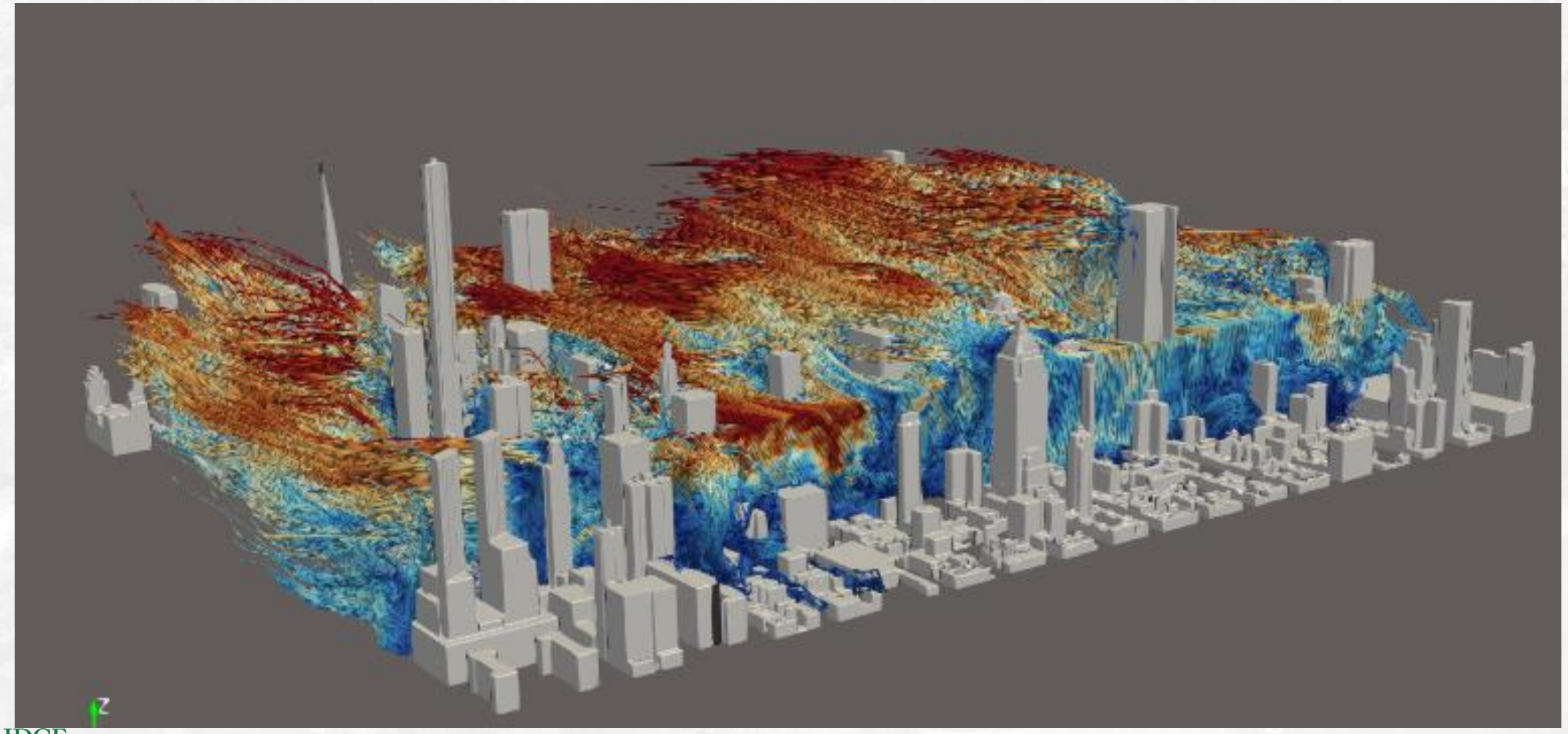
- “Out of the box”
- Deeper collaboration
- High-end rendering

Use Case: Turbulent Wind Turbine Flow

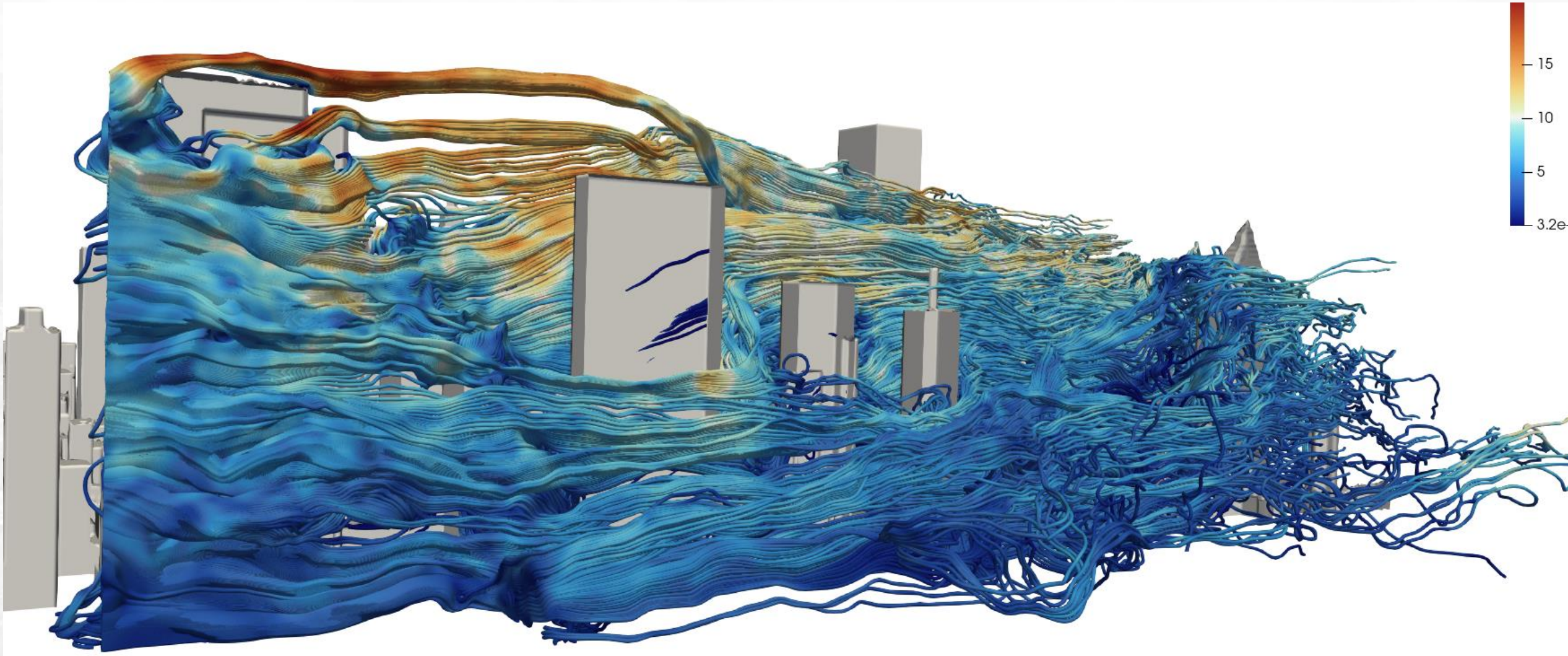
- Data in netCDF (.nc) format
  - ParaView supports CF convention
  - Can interpret arrays as regular grids with conventions for point locations and time dimension

Use Case: Turbulent Flow through New York City

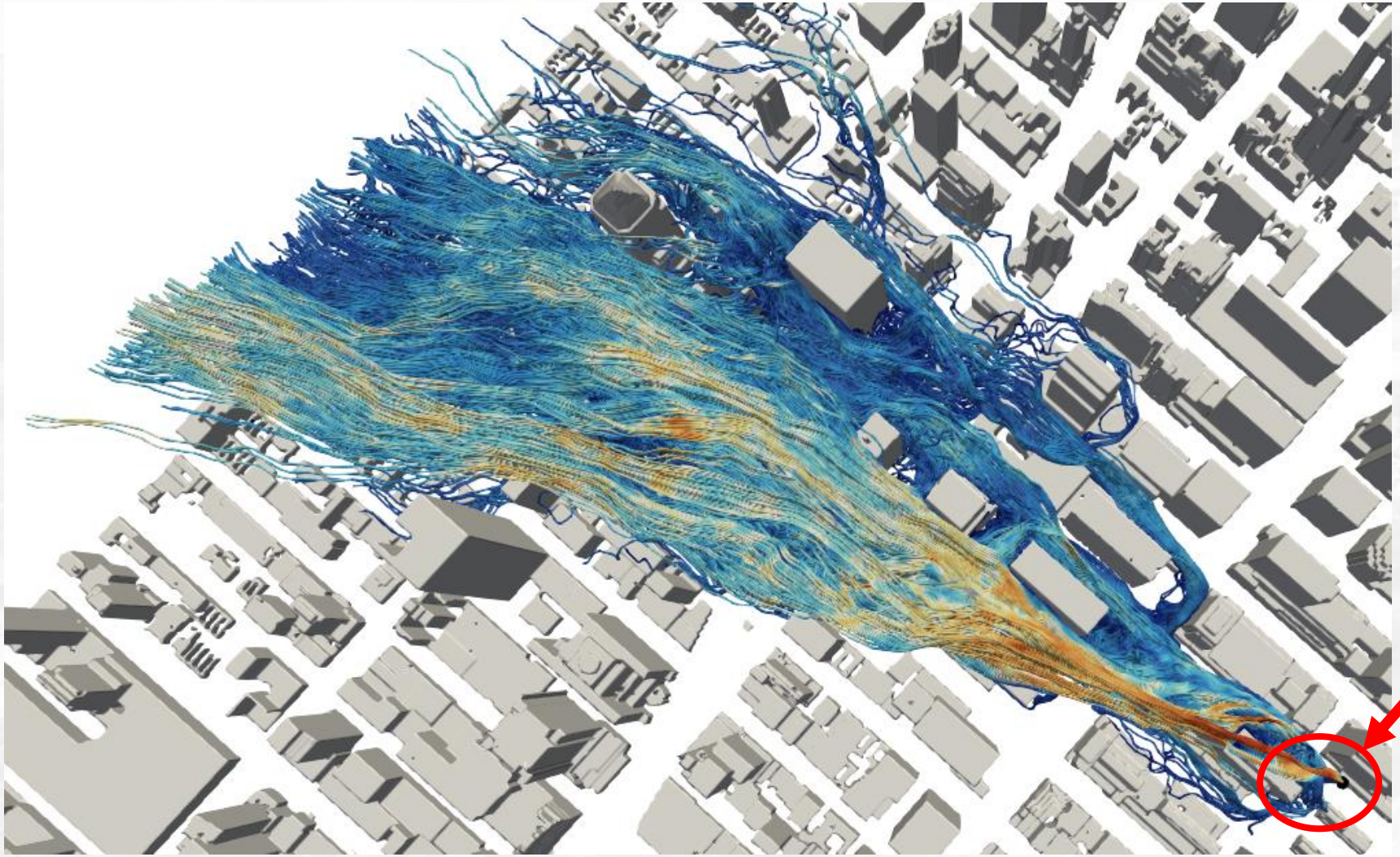
- Data in netCDF (.nc) format loaded in ParaView
- Scalar and vector quantities



Use Case: Turbulent Flow through New York City



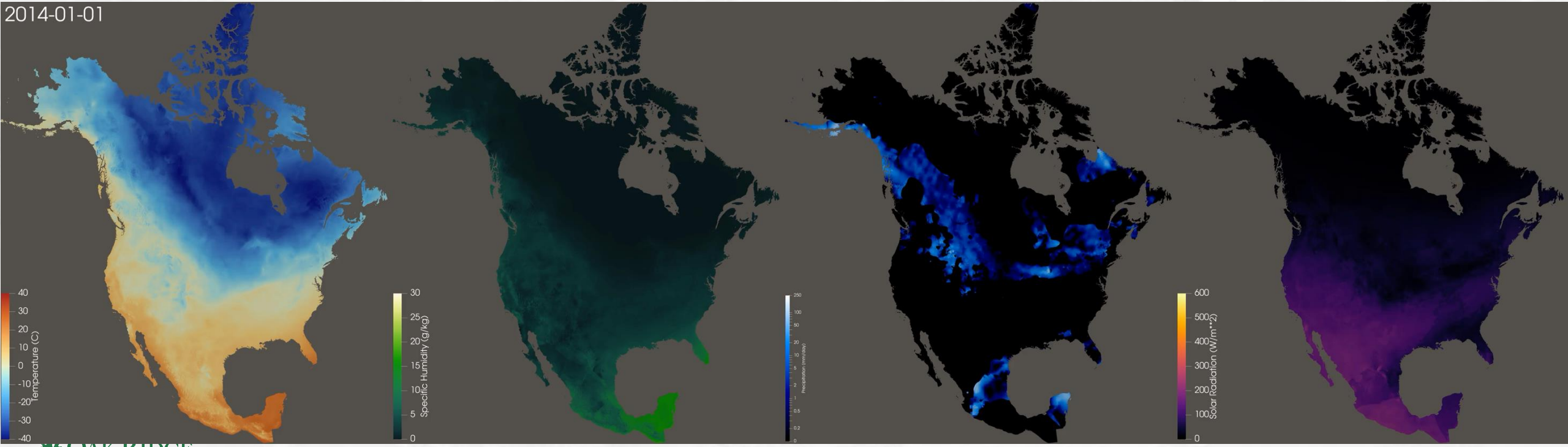
Use Case: Turbulent Flow through New York City



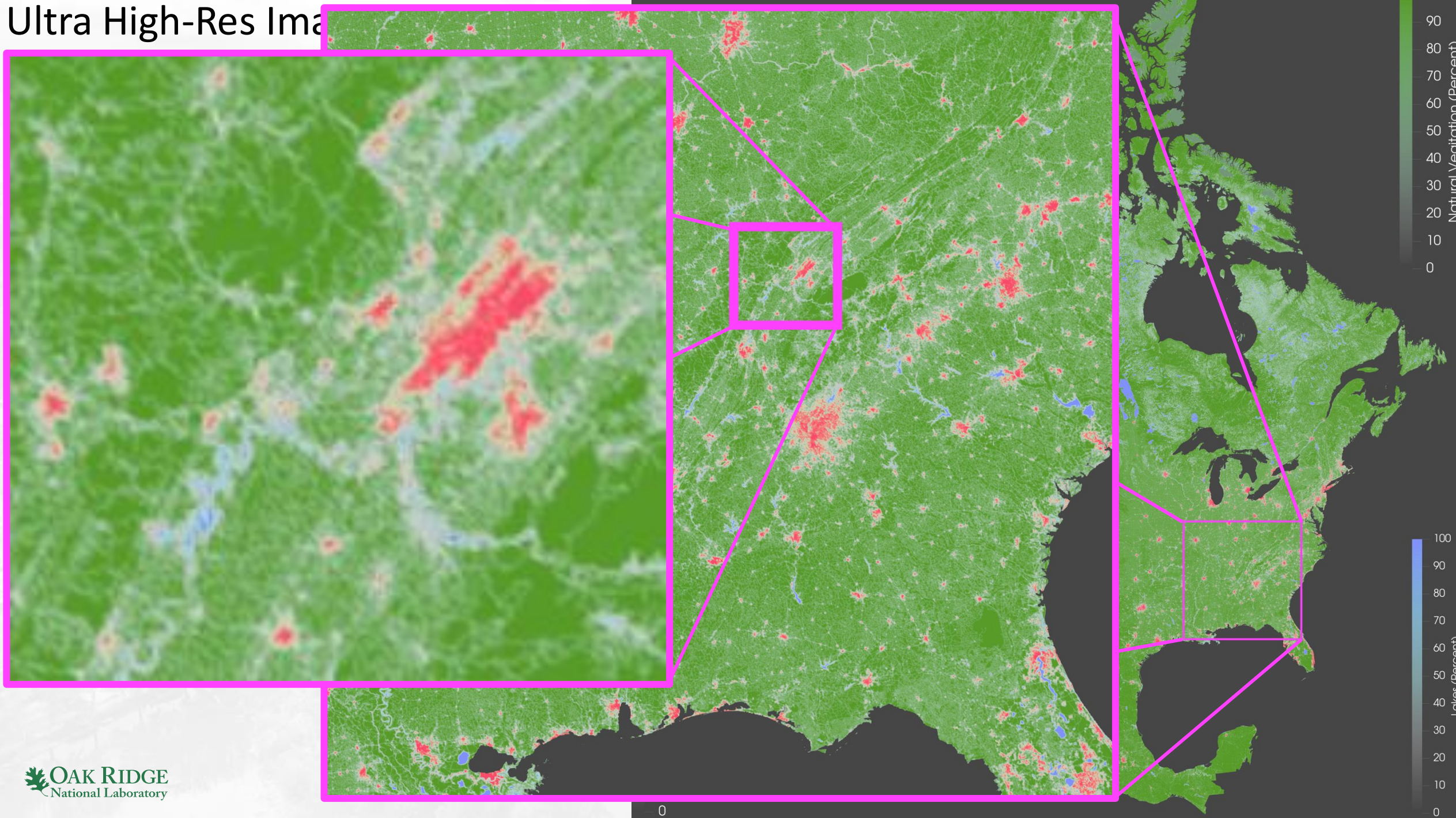
Reverse flow to a destination

Use Case: Daymet High-Resolution, Long-Term, Daily Weather Simulation

- 1 km^2 resolution, multiple weather variables, 3 hr time frequency
- Data in netCDF (.nc) format
  - ParaView supports CF convention
  - Can interpret arrays as regular grids with conventions for point locations and time dimension
- Threshold away invalid values to retrieve irregular shapes



Ultra High-Res Ima



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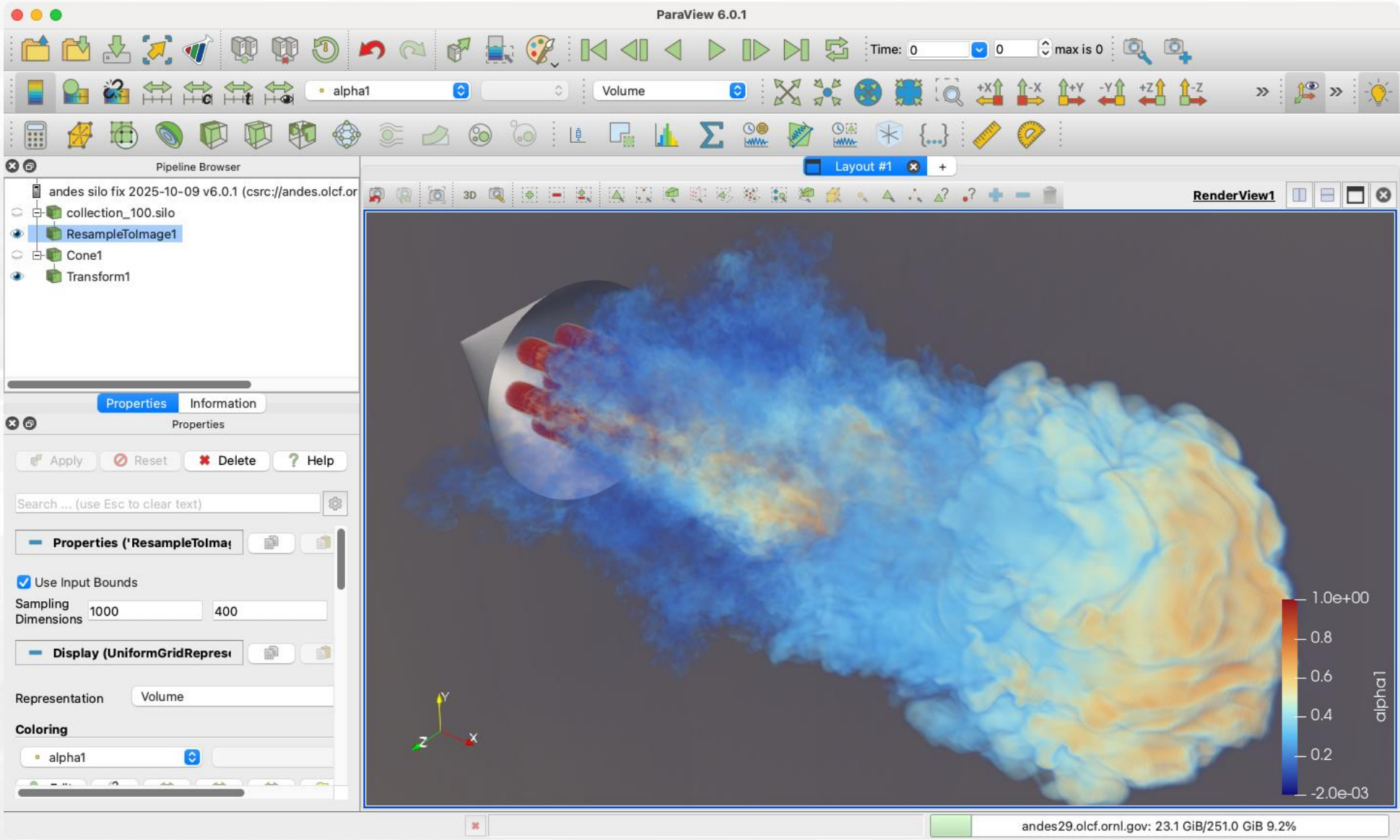
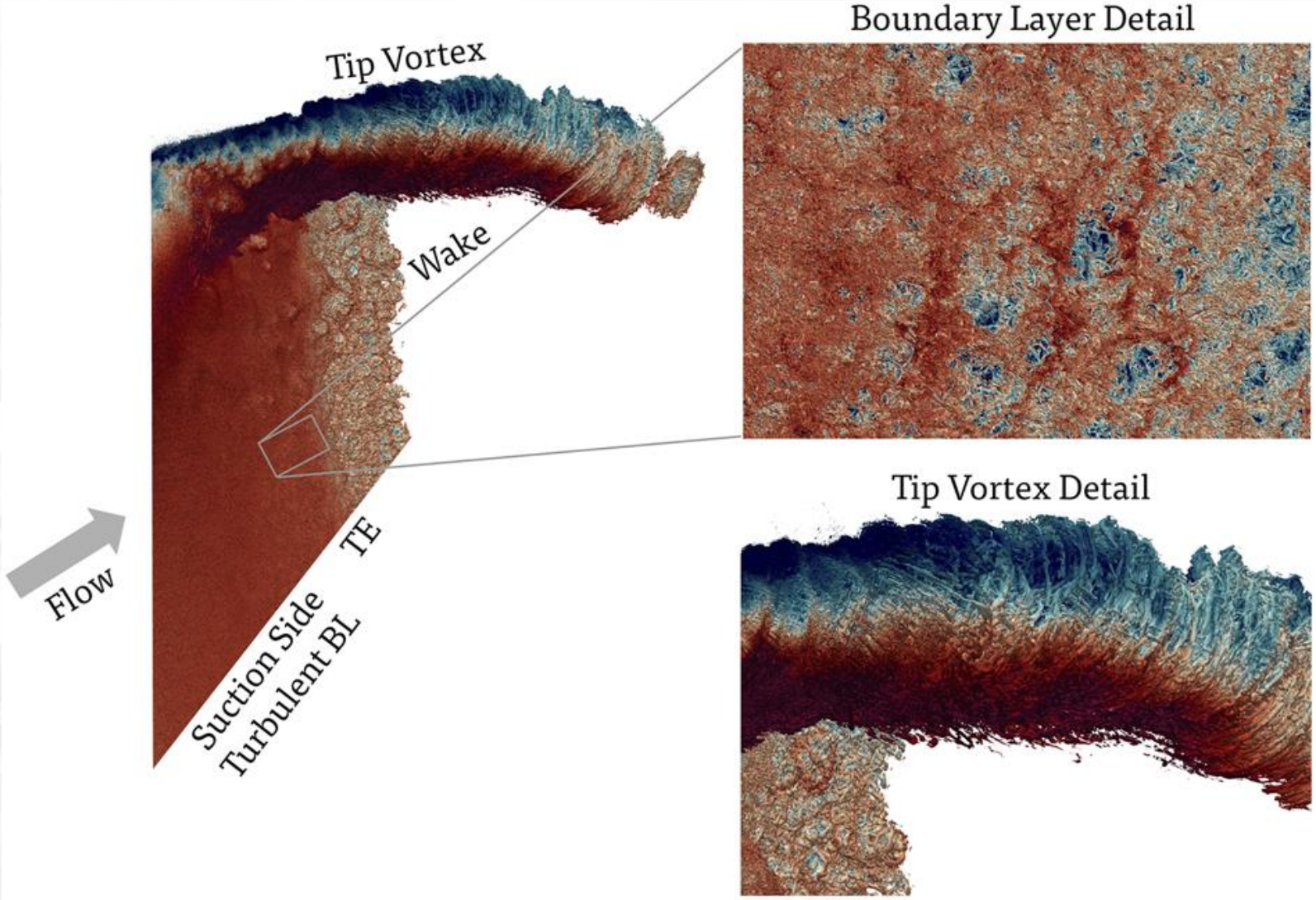
Boost Rocket Flow

- Largest CFD simulation to date
- Data written in multiblock SILO format
  - Required fix of reader from another lab
- Data resample on regular grid then volume rendered
- Polygonal models added for context



GE Aerospace

- Load Fides data
  - ADIOS bp format + JSON metadata
  - Working with GE to write out metadata in this format
- Use calculator for derived quantities
- Use contour on Q-criterion to visualize turbulence



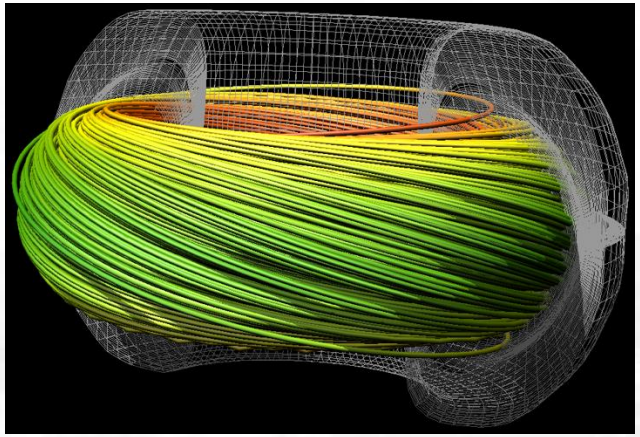
ORBIT-2: Foundation Model for Global Climate Downscaling

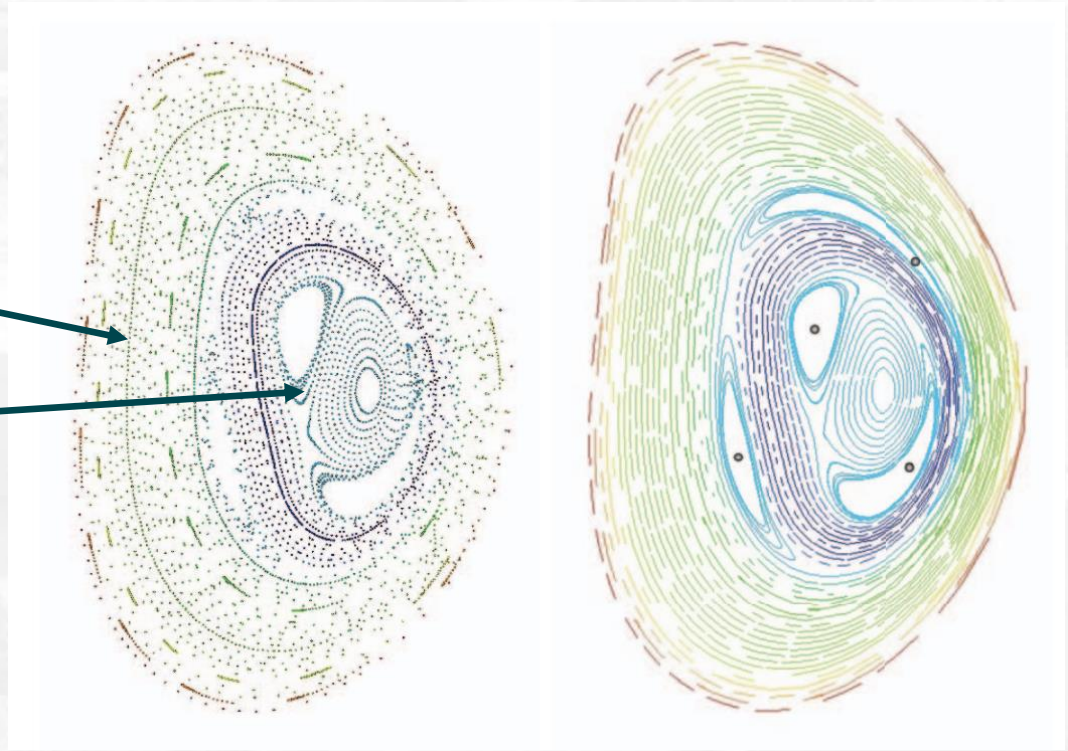
- Simulation output to netcdf files
- Mapping data to sphere
- NASA satellite image for earth surface
- Movie frames generated by ParaView
- Python script for annotations, sequencing, blending and final compositing

Video showing ERA5 input at 28 km resolution (left) and ORBIT-2 downscaled output at 7 km resolution (right) over a six-month winter period (Oct 2019 – March 2020).

Poincaré Analysis for Fusion

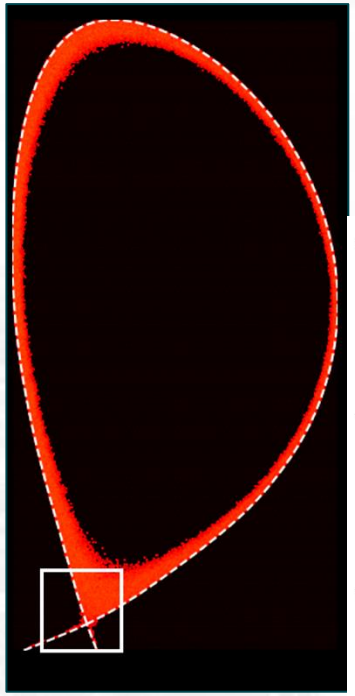
- Magnetic fields critical for driving and controlling plasma
- Periodic nature of field lines makes traditional flow visualization difficult
- Poincaré analysis provides a 2D view of the magnetic field evolution

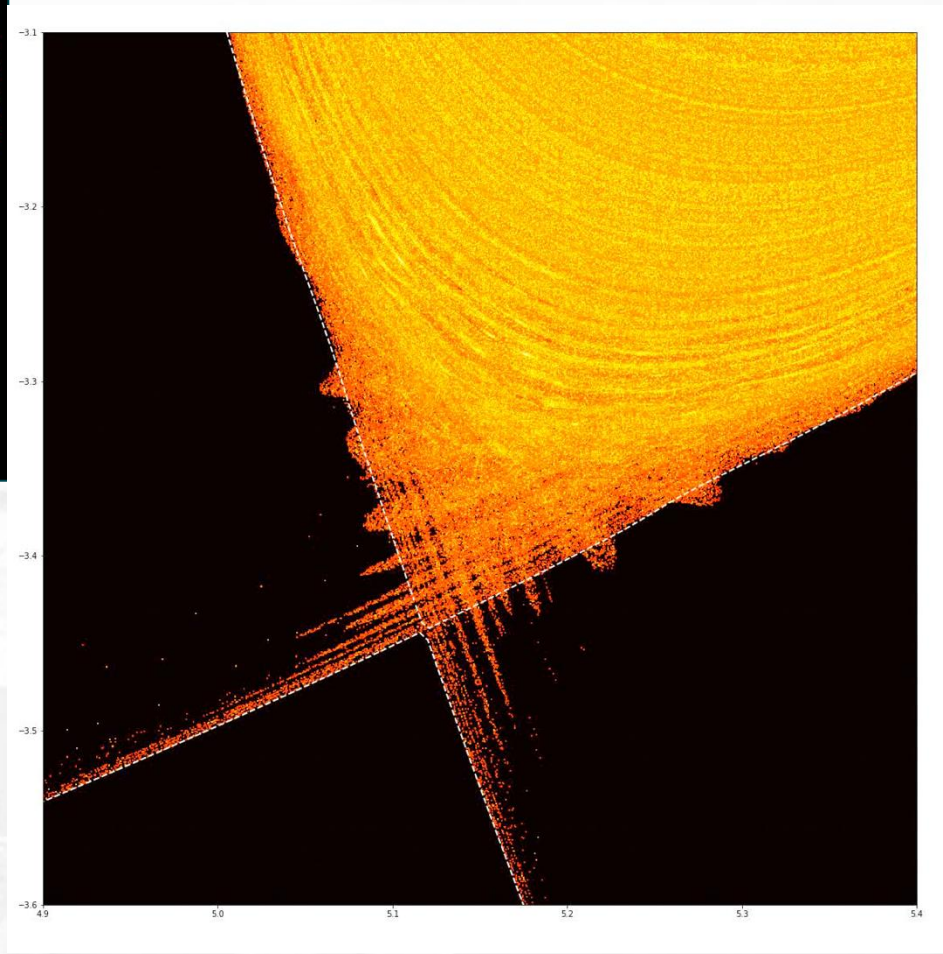




Poincaré Analysis for Fusion

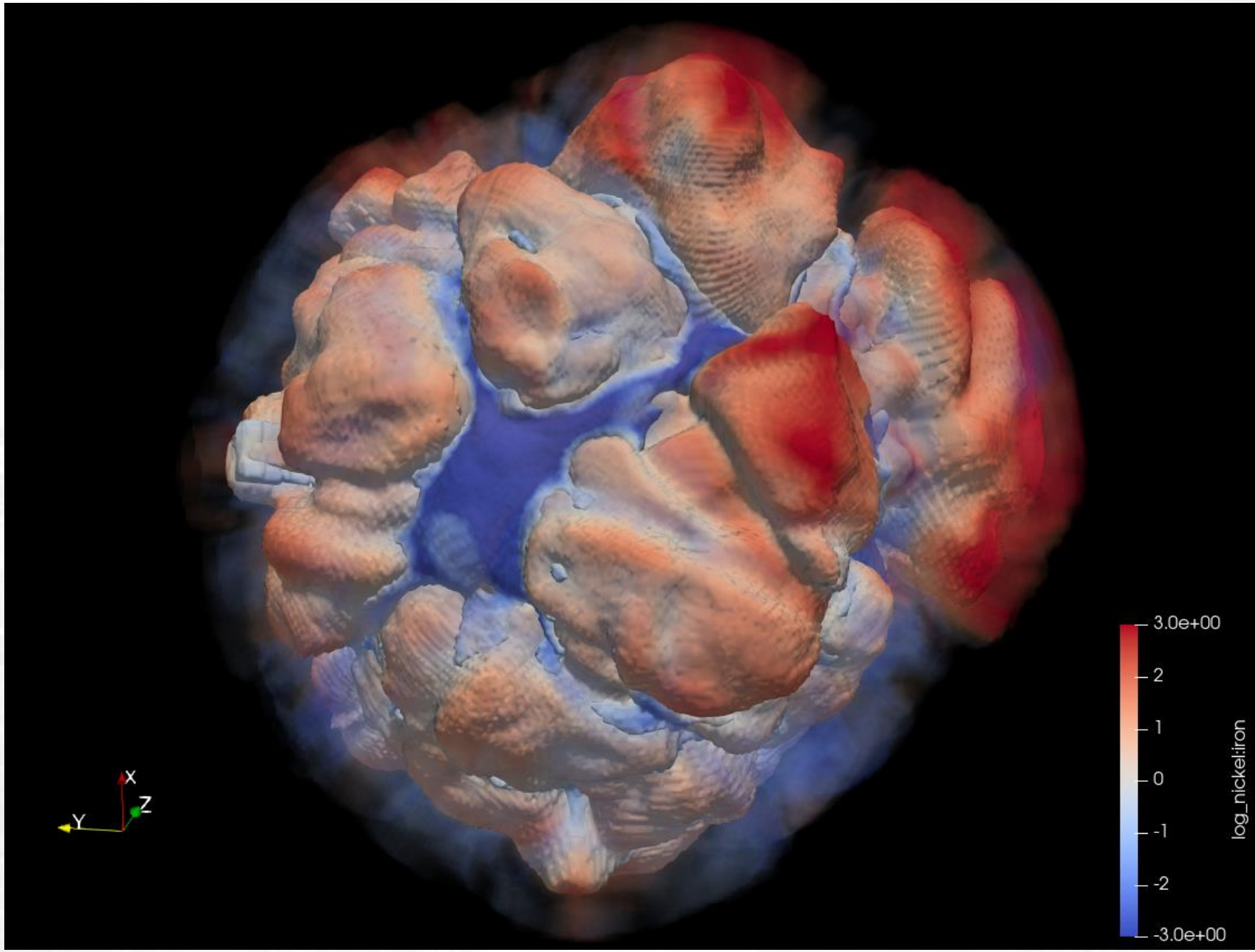
- Detailed analysis requires:
  - 30-50k particles
  - 1-3k orbits
- Existing tools very slow
  - ~1 hour per timestep
- Magnetic field line calculation is complex and code specific
- GPU implementation in Viskores
  - From 1 hour to 3 minutes
  - Full time evolution now possible





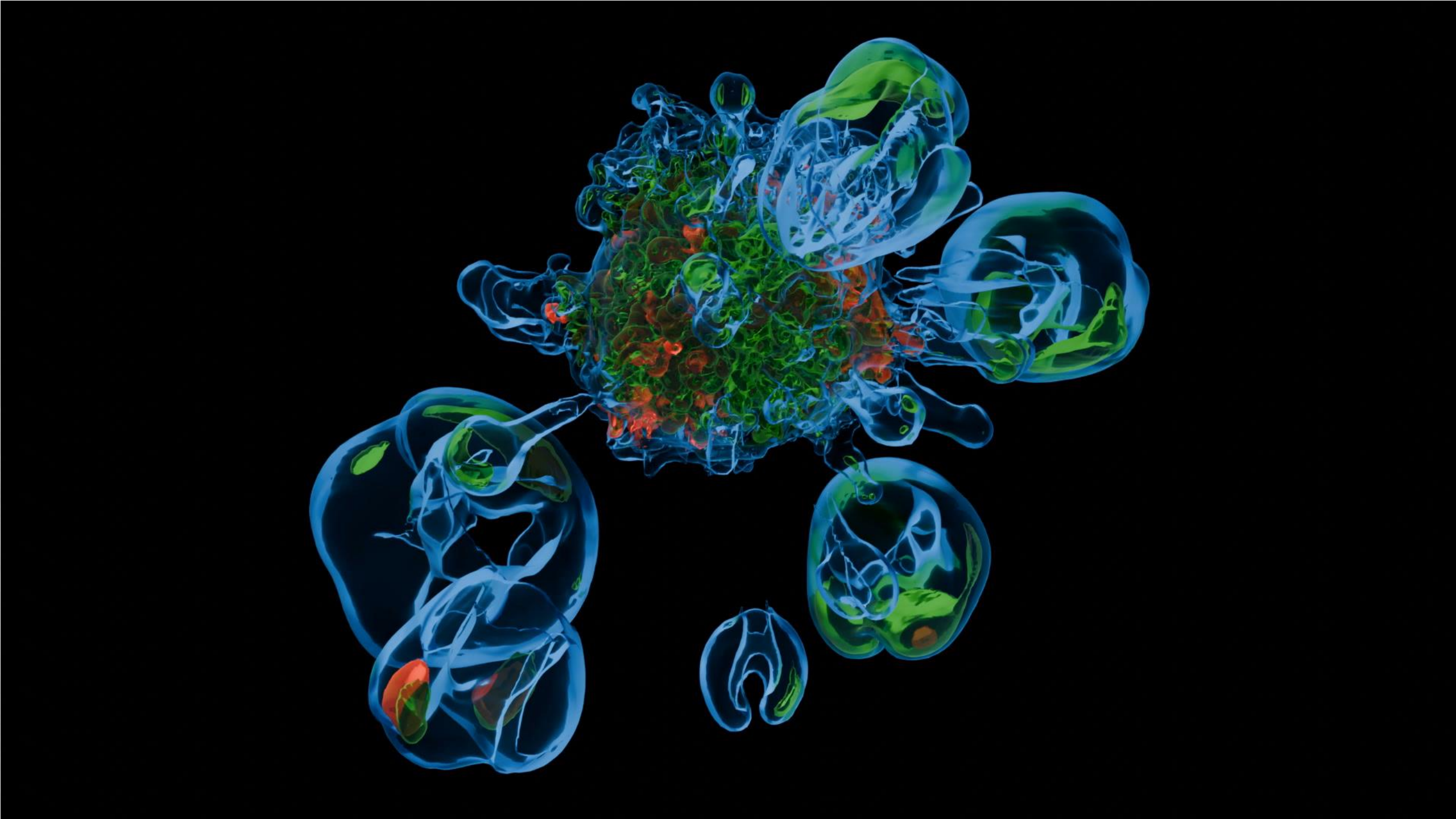
Supernova

- Simulation output in FLASH format
- This rendering completely in ParaView
- Data converted from polar to Euclidean coordinates
- Contours show mass fraction of Iron and Nickel, respectively
- Volume rendering shows ratio of Nickel to Iron



Supernova

- Simulation outputs in FLASH format
- Use VisIt to extract iso contours of He4 and 2 Ni isotopes
- Surfaces exported to STL
- Blender used for lighting, camera movement, materials and rendering



Questions